Science of the Total Environment 610–611 (2018) 316–332

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Review

Liming impacts on soils, crops and biodiversity in the UK: A review

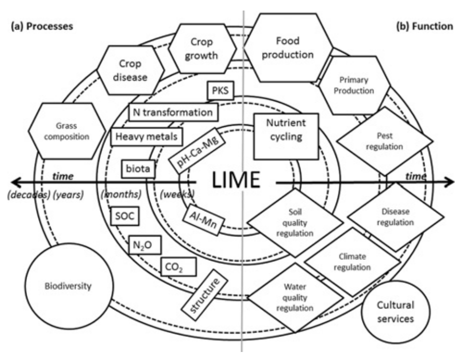
J.E. Holland [a,*], A.E. Bennett [a], A.C. Newton [a], P.J. White [a], B.M. McKenzie [a], T.S. George [a], R.J. Pakeman [b], J.S. Bailey [c], D.A. Fornara [c], R.C. Hayes [d]

[a] The James Hutton Institute, Invergowrie, Dundee DD2 5DA, UK
[b] The James Hutton Institute, Craigiebuckler, Aberdeen AB15 8QH, UK
[c] Agri-Food and Biosciences Institute, Newforge Lane, Belfast BT9 5PX, UK
[d] New South Wales Department of Primary Industries, Wagga Wagga Agricultural Institute, Pine Gully Road, Wagga Wagga, NSW 2650, Australia

HIGHLIGHTS

- Liming has numerous far reaching impacts on soil and plant processes and function.
- Liming impacts on soils are positive such as increased nutrients and biota.
- Liming crops and grassland is beneficial to yield and quality and for grazing stock.
- Liming impacts on biodiversity vary significantly with evidence of positive effects.
- A qualitative framework shows how liming impacts change with time.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 5 May 2017
Received in revised form 14 July 2017
Accepted 2 August 2017
Available online 11 August 2017

Editor: D. Barcelo

Keywords:
Agriculture
Soil acidity
Soil management
Crop response
Ecosystem services

ABSTRACT

Fertile soil is fundamental to our ability to achieve food security, but problems with soil degradation (such as acidification) are exacerbated by poor management. Consequently, there is a need to better understand management approaches that deliver multiple ecosystem services from agricultural land. There is global interest in sustainable soil management including the re-evaluation of existing management practices. Liming is a long established practice to ameliorate acidic soils and many liming-induced changes are well understood. For instance, short-term liming impacts are detected on soil biota and in soil biological processes (such as in N cycling where liming can increase N availability for plant uptake). The impacts of liming on soil carbon storage are variable and strongly relate to soil type, land use, climate and multiple management factors. Liming influences all elements in soils and as such there are numerous simultaneous changes to soil processes which in turn affect the plant nutrient uptake; two examples of positive impact for crops are increased P availability and decreased uptake of toxic heavy metals. Soil physical conditions are at least maintained or improved by liming, but the time taken to detect change varies significantly. Arable crops differ in their sensitivity to soil pH and for most crops there is a positive yield response. Liming also introduces implications for the development of different crop diseases and liming management is adjusted according to crop type within a given rotation. Repeated lime applications tend to improve grassland biomass production, although grassland response is variable and indirect as it relates to changes in nutrient availability. Other indicators of liming response in grassland are detected in mineral content and herbage quality which have implications for livestock-based production systems. Ecological studies have shown positive impacts of liming on biodiversity; such as increased earthworm abundance that provides habitat for wading birds in upland grasslands. Finally, understanding of liming impacts on soil and crop processes are explored together with functional aspects (in terms of ecosystems services) in a new qualitative

* Corresponding author.
E-mail address: Jonathan.holland@hutton.ac.uk (J.E. Holland).

http://dx.doi.org/10.1016/j.scitotenv.2017.08.020

framework that includes consideration of how liming impacts change with time. This holistic approach provides insights into the far-reaching impacts that liming has on ecosystems and the potential for liming to enhance the multiple benefits from agriculturally managed land. Recommendations are given for future research on the impact of liming and the implications for ecosystem services.

Contents

1. Introduction

Healthy and fertile soil is fundamental to our ability to achieve food security and agricultural sustainability, but is challenged due to poor management and environmental change. Increasingly soils are being degraded and becoming marginal for production. Recent concerns about global drivers of soil degradation include salinization, erosion (wind and water-borne) and acidification and contamination (FAO, 2015). The situation is made more difficult by the need to increase food production to feed an increasing global population. Consequently, there is global interest in the development and implementation of sustainable agricultural practices. Practices need to maintain soils' ability to produce food while also delivering other key ecosystem services such as the regulation and storage of nutrients and C in soils.

The benefits of applying limestone to ameliorate acidic soils have been known for centuries. For instance, the use of marl and burnt lime was a central part of the land improvement system that was developed during the eighteenth century in Berwickshire, Scotland (Dodgshon, 1978). Agriculture continues to develop and change and the focus now lies not solely on production, but also on maintaining a healthy environment. Thus, today the challenge for liming (and other farm practices) is to achieve sustainable management in a whole system approach (Gibbons et al., 2014). The impact of liming is far-reaching and while previous research on liming has strongly focused on individual components of soil processes or on single crops, there is an urgent need to better understand the broader impacts of liming.

The primary management 'problem' that liming addresses is soil acidification. Acidification is caused both by natural processes (via C, N and S cycling) and anthropogenic activities. Acid deposition threatens ecosystem health (especially water quality) and liming has had an important mitigation role (Clair and Hindar, 2005). Recently, sulphur deposition has decreased across the UK and thus the acidic load has declined appreciably (Kirk et al., 2010). Another cause of acidification is the application of nitrogen fertilisers. There are global concerns regarding acidified arable land, particularly in China, where it is a major challenge (Guo et al., 2010). Therefore, questions are being asked about the potential mitigation value of lime. The impacts of liming on greenhouse gas emissions are complex and there are markedly different potential changes in emissions between different gases. A recent comprehensive review reports on this further (Kunhikrishnan et al., 2016), but briefly some examples include: decreased nitrification-induced nitrous oxide (N_2O) production, increased methane (CH_4) oxidation, and depending on the antecedent soil pH, liming material can act either as a net source or a net sink for carbon dioxide (CO_2).

From an agricultural perspective the principal driver for lime application is soil pH. A recent report indicates that >40% of arable soils in the UK have a soil pH <6.5 and 56% of grassland soils have a pH <6.0 (PAAG, 2015) (Fig. 1). The Professional Agricultural Analysis Group (PAAG) report is based on the collation >170,000 soil analyses (pH, P, K, Mg) from across the UK. These results indicate significant differences in soil pH across the UK reflecting differences in soil types and dominant land (crop) uses in different regions. Fig. 1 shows that >60% of samples from Wales and Scotland had soil pH <6 compared with 1% in East Anglia. This suggests there are significant areas where lime application would be recommended based upon good practice in England and Wales (DEFRA, 2010) and in Scotland (Sinclair et al., 2014). The reports